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KARL SCHWARZSCHILD.[1]

The war exacts its heavy toll of human life, and science is not spared. On our side we have not forgotten the loss of the physicist Moseley, at the threshold of a great career; now, from the enemy, comes news of the death of Schwarzschild in the prime of his powers. His end is a sad story of long suffering from terrible illness contracted in the field, borne with great courage and patience. The world loses an astronomer of exceptional genius, who was one of the leaders in recent advances both in observational methods and theoretical researches.

Karl Schwarzschild was born on October 9, 1873. His mathematical ability developed with almost precocious rapidity. His first scientific papers, relating to the theory of determining orbits from observations, were published in the *Astronomische Nachrichten* in 1890; they show such wide reading combined with original insight that it seems almost incredible that the author was a schoolboy of sixteen. On taking his university course, he studied at first at Strasburg under Becker, and afterwards at Munich. There he came under the inspiration of Seeliger's teaching, which apparently was the basis of his later researches on stellar statistics; he often expressed regret that the work of Seeliger was so little understood in other countries. His career after leaving the university is divided into three stages: he was at first Assistant in the von Küffner Observatory, Vienna; in 1901 he became Professor and Director of the Observatory at Göttingen; finally in 1909 he succeeded Vogel as Director of the Astrophysical Observatory, Potsdam.

Schwarzschild's researches were amazingly varied. He was a master of almost all branches of physical and mathematical science. It is difficult to pick out any one work as his special title to eminence; for it was not his way to write exhaustive memoirs—to wring his subject dry. He made his contribution—some clear-cut theorem marking a definite advance, which others might follow and carry out in detail—and then he passed on to some new point on which his genius could throw light.

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[1] We reprint this admirable summary of the work of a great German astronomer from the English astronomical journal, *The Observatory* (August, 1916), both because it is the most adequate account of Schwarzschild's scientific career that has been published and because it is a fine example of that spirit of generous appreciation of an enemy's greatness which should characterize all honorable men, but which seemed, for a time, to be in danger of being lost in the present war.
PUBLICATION COMMITTEE.

In practical astronomy perhaps his chief work was his determination of photographic magnitudes. This was one of his earliest researches, being started at Vienna and developed at Göttingen. His method was to draw out the star-image into a uniform patch of light, of which the density or greyness could be measured in order to ascertain the brightness; this spreading out of the image was accomplished partly by displacing it out of focus and partly by making it travel in a definite manner over an area of the plate. With the coöperation of his assistants at Göttingen, he compiled in this way the "Göttingen Aktinometrie," a catalogue of photographic magnitudes of stars between Dec. 0° and +20° down to the limit $7^m.5$, reduced to an absolute scale. This work brought out very clearly the close relation between the colour and spectral type of a star, and also the fact that it is the stars of intermediate colour—the yellow stars—which have the largest proper motions.

In this connection it may be mentioned that Schwarzschild was the first to employ a coarse grating in front of a telescope object-glass—a plan which is now often used both for determining photographic magnitudes and measuring star colour. Schwarzschild, however, did not apply it to these purposes, but measured the separations of double stars with it, using it as a kind of double-image micrometer; he varied the distance between the two images by inclining the grating at different angles to the axis of the telescope. The method does not seem to have been tried on a large scale, though the experiments with a small telescope gave good results.

To Schwarzschild we owe the theory of radiative equilibrium of the Sun. It seems probable that this theory represents the observed phenomena better than any other; but, like much of Schwarzschild's theoretical work, the value lies not so much in the correctness of the physical assumptions as in the clear formulation of the problem, enabling us to appreciate the possible alternatives and the manner in which they affect the solution. His great step was to recognize that there are three types of equilibrium of the Sun's atmosphere according as conduction, convection, or radiation is the most effective in transferring heat. By working out the last alternative he brought the theory into a fit state to be compared with observation, and the value of this would have been none the less great even if observation had been far less favourable to the radiative hypothesis than was actually the case.

Another important result was his calculation of the pressure of radiation on small solid particles—of much interest in connection with the repulsion of the tails of comets by the Sun. For moderately large particles sunlight exerts a pressure proportional to the cross-section, whereas the force of the Sun's gravitation is proportional to the cubical contents. It follows that as the size of the particle decreases the light-pressure decreases less rapidly than the gravitation, so that ultimately the former predominates and the particle is repelled from the Sun. But the repulsion does not increase indefinitely, because, when the size of the particle becomes comparable with the wave-length of light, diffraction takes place. For a very small particle the light-waves bend round instead of being stopped. There is thus a certain size of particle for which the repulsion is a maximum, and Schwarzschild calculated that this upper limit is about 19 times the solar attraction. In view of the fact that the repulsive forces observed in comet's tails are sometimes considerably greater than this, this limit to the efficacy of light-pressure is of great interest.

In stellar statistics Schwarzschild's best-known work was his ellipsoidal hypothesis of stellar motions. Kapteyn had in 1904-5 published a summary of his celebrated investigation which showed that there are two streams of stars. In later work, for the purpose of precise mathematical treatment, it had seemed best to take the two streams quite literally, and represent the motions as due to two independent systems of stars passing through one another. Schwarzschild, however, proposed a mathematical treatment of the phenomena, which retained the essential unity of the system; the double-streaming was, of course, duly represented in his formulæ, but he avoided any suggestion that it arose from the encounter of two clusters. The ellipsoidal hypothesis is a most elegant piece of mathematics, and is specially adapted to simplify many of the problems of stellar motions which have arisen. Without it much of the recent progress would have been impossible. It is characteristic of Schwarzschild that his whole work on this subject, which has had so great an influence on stellar investigation, is contained in two papers of 28 pages in all. He made many contributions to other branches of stellar investigation which are too technical to be described here: but it may be mentioned that his general solution of the integral equation of stellar statistics appears to be not only of astronomical value but a noteworthy contribution to pure mathematics.

Professor Baker, in the last number of the *Observatory,* brought to light the almost forgotten fact that an important point in the theory of exchange of stabilities in dynamics is due to Schwarzschild. Outside astronomy, his papers ranged over geometrical optics, electrical theory, thermodynamics, and the navigation of balloons. His last work was a paper on the Quantum Theory published by the Berlin Academy of Sciences; he corrected the proofs on his sick-bed.

Schwarzschild's characteristics were not those which are usually associated with the scientists of his nation. Keen and restless, his nature was remote from the slow-plodding German character. He was a most enthusiastic mountaineer, and had accomplished some of the most desperate ascents in the Alps. He was full of the adventurous spirit, in winter sports in Switzerland, in early Zeppelin ascents—and in the last great adventure of all. His writings are a model of clearness and concise expression; he never inflicts on us the unbalanced detail and the mazes of analysis—the penalty of "German thoroughness"—which render so many German scientific writings unattractive. He goes straight to his point without an unnecessary sentence. It would be paying an ill-service to the memory of one who gave the final proof of devotion to his country, to seek by these traits to disassociate him from the rest of his nation. We would rather say that through him a new spirit was arising in German astronomy from within, raising, broadening and humanizing its outlook; and we are confident that he has left behind an influence which will enlarge and revivify the old traditions.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1917.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon...	Jan.	7th,	$11^h 42^m$	P.M.	Full Moon..	Feb.	6th,	$7^h 28^m$	P.M.
Last Quarter.	"	16th,	3 42	A.M.	Last Quarter	"	14th,	5 53	P.M.
New Moon...	"	22d,	11 40	P.M.	New Moon..	"	21st,	10 9	A.M.
First Quarter.	"	29th,	5 1	P.M.	First Quarter	"	28th,	8 44	A.M.

The year 1917 will have the maximum number of *eclipses,* seven. Of these, three are of the Moon and four of the Sun. There will not be another year with seven eclipses until 1935, and then there will be two of the Moon and five of the Sun. The last previous occurrence of this latter phenomenon was in 1823. Three lunar eclipses occurred in 1908, but in that year there were only three solar, making a total of six. The average number of eclipses per year is four or five, but the number may be as low as two. In this case, which happened in 1904, both of the eclipses were solar and both central.

There will be two eclipses during January; the first is *a total eclipse of the Moon* on the night of January 7-8, and will be visible thruout the United States. The circumstances of the eclipse are as follows, Pacific Time:

Moon enters shadow	Jan.	7th,	$9^h 50^m$	P. M.
Total eclipse begins	"	7th,	11 0	P. M.
Middle of the eclipse	"	7th,	11 45	P. M.
Total eclipse ends	"	8th,	12 29	A. M.
Moon leaves shadow	"	8th,	1 39	A. M.

The duration of totality, not quite an hour and one-half, is longer than the average, although not a maximum.

The second eclipse of the year occurs on January 22-23, and is *a partial eclipse of the Sun.* It will not be visible in the Western Hemisphere. The regions of visibility are Europe, except the British Islands and Spain, Northern Africa and Western Asia. The greatest obscuration of the Sun is not quite three-quarters of its diameter.